INFLUENCE OF LARCH ON THE MOUNTAIN-PODZOLIC SOILS OF THE URALS

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The investigations by a number of authors have demonstrated the positive effect of larch on the soil, i. e., its physical-chemical properties [1, 6, 10, 12]. The influence of larch on the soil in natural plantations has been studied only by Gradoboyev [2].

In the summer of 1962 we set up 15 experimental plots in young pine-larch stands in compartment 32 in the Sukhogor forestry of the Lobva lumber industry (Sverdlovsk Oblast'). A detailed study of the soil profile and of the litter were made on the three most characteristic plots to determine the influence of various numbers of larch in a stand on soil formation. The plots were located within the same economic unit at a minimum distance to each other and had the most similar environmental conditions.

As we can see from Table 1, the selected plantations have sufficiently similar plantation characteristics and are of relatively high density. The stands developed after clean cutting in the 1920's. The number of larches in the composition of the stands varied from 1 to 5 economic units.

The areas studied belong to the zone of mountain-podzolic soils underlain by basic effusive Upper Silurian and Devonian rocks, represented by diabases. The sampling area is located on a flat summit of a low ridge. The microrelief is flat with small elongated depressions from 0.2 to 0.6 m long.

The regrowth consists of pine, spruce, cedar and larch (10-15 years) of medium density. The underbrush is thin and consists of dog rose and mountain ash. The grass cover is represented by mountain cranberry, whortelberry, stone-fruit, forest geranium, northern two-flower, bifoliate maianthemum, and green mosses.

The morphological description of soil profiles is given below.

Description of the profile in experimental plot No. 6

A_0' 0-2 cm	Friable layer of dry undecomposed residues of needles, branches, cones, interwoven with green mosses and grass stems.
A_0'' 2-3 cm	Semi-decomposed residues of grasses, roots, needles, leaves, branches and cones.
A_0''' 3-6 cm	Decomposed, unidentifiable litter-fall residues of a dark-brown color, interwoven roots with traces of mineralization and earthworms.
A_1 6-18 cm	Gray-cinnamon brown, weakly humified, with a fine powdery structure, friable moist clay loam with a great number of roots. Gradually changes into the A_2 subhorizon.
A_2B_1 18-46 cm	Light cinnamon-brown, fine

Table 1

Characteristics of experimental plots in a berry-patch pine forest

Experimental plot No.	Composition	Age, years	Average height	Site quality	Density according to the standard table	Amount, m^3
6	8P1L1B	37	13,2	II	1,32	237
7	7P2L1B	36	13,5	II	1,41	253
1	4P5L1B	36	13,1	II	1,30	232

Note: Comma represents decimal point

	blocky, powder-like with stone inclusions, compact, moist clay loam with traces of small roots.
B_2 46-60 cm	Light cinnamon-brown, very compact with white spots and stone inclusions, dry clay loam.
C 60 cm and below	Clay, underlain by diabases.

Description of the profile in experimental plot No. 7

A_0' 0-1.5 cm	Friable layer of dry non-decomposed residues of needles, branches and cones, interwoven with green mosses and grass stems in some places.
A_0'' 1.5-2.5 cm	Semi-decomposed residues of needles, leaves, roots, branches and cones.
A_0''' 2.5-5.5 cm	Decomposed unidentifiable litter residue of a dark-brown color, interwoven with roots, with traces of mineralization and earthworms.
A_1 5.5-17 cm	Gray-yellow with a fine blocky powder-like structure, damp clay loam with a large number of roots, with humus spots and veins. Gradually changes into the A_2 subhorizon.
A_2B_1 17-40 cm	Light cinnamon-brown with a blocky-powdery structure, very compact damp clay loam with traces of fine roots and stony inclusions.
B_2 40-58 cm	Light cinnamon-brown, dry, very compact with a large number of stone inclusions.
C 58 cm and below	Parent material - diabase.

Description of the profile in experimental plot No. 1

A_0' 0-0.5 cm	Friable layer of dry non-decomposed residues of branches, needles and cones.
A_0'' 0.5-1.5 cm	Semi-decomposed residues of needles, branches, cones and grasses.
A_0''' 1.5-4 cm	Decomposed litter residue of a black-brown color, interwoven with roots, with traces of mineralization and earthworms.
A_1 4-18 cm	Gray cinnamon-brown damp slightly humified clay loam with a blocky-powdery structure. Gradually changes into the A_2 subhorizon.
A_2B_1 18-42 cm	Light cinnamon-brown damp clay loam with a slightly blocky structure, compact, with a large number of small roots.
B_2 42-55 cm	Light cinnamon-brown, structureless dry clay loam, compact, with stone inclusions.
C 55 cm and below	Gray-greenish with whitish and cinnamon brown spots, very compact, dry clay loam with occasional traces of fine roots, with a large amount of stone inclusions, underlain by diabase.

The morphological descriptions of soils in the experimental plots are similar and suggest the development of soil formation of the sod-podzolic type. The ill-defined podzolic horizon, common to all the profiles, indicates that podzol formation is weakly developed. The differences in the development of the humus horizon are small, within the limits of the moderately soddy category. There is an insignificant increase in the thickness of the accumulation horizon with the increase in the number of larches in the composition of the plantations. There are no differences in the degree of development of podzolization because of the vagueness of the eluvial horizon and the lack of a clear transition from this horizon to the underlying genetic layers. This has been also noted by Gradoboyev [2] in the soils of natural larch forests in the Altay, Western Sayan, the Kuznetsk Ala-Tau and Tuva.

The soils described by us have been classified in the category of sod weakly podzolic soils according to their morphological features. They differ in the thickness of the litter (Table 2).

As we can see from the data given here, the total thickness of the litter increases as the number of larches decreases in the composition of the plantations. The relationship of the thickness of subhorizons testifies to the satisfactory course of the decomposition of organic residues (the development of the A_0''' subhorizon and the insignificance of the A_0'' subhorizon), which is also verified to some extent by the presence of earthworms.

The litter mass was determined by weighing for each profile 10 areas measuring 1 m^2 each. The areas were established in various places, an average sample was taken in each and its weight was determined in an absolutely dry state. Then the amount was converted to a hectare basis. As we can see from Table 2, the amount of litter varies considerably: amount of litter decreases as the number of larches in the stand composition increases. A similar phenomenon was noted by Zonn [3, 4] and Rozanova [9]. This contradicts the data of Kartashov [5], who notes that the amount of litter in larch plantations (and also the amount of annual litter-fall) exceeds the amount of litter in pine plantations.

Table 2

Litter thickness

Experimental plot No.	Composition of the plantation	Thickness of subhorizons, cm			Total	Weight of absolutely dry mass, metric tons/ha
		A_0'	A_0''	A_0'''		
6	8P1L1B	2,0	1,0	3,0	6,0	34,1
7	7P2L1B	1,5	1,0	3,0	5,5	31,7
1	4P5L1B	0,5	1,0	2,5	4,0	30,3

Note: Comma represents decimal point

Table 3

Moisture capacity and water-permeability of litter

Experimental plot No.	Composition of plantations	Moisture capacity, %			Coefficient of infiltration, cm/sec		
		A_0'	A_0''	A_0'''	A_0'	A_0''	A_0'''
6	8P1L1B	135	192	118	0.193	0.080	0.006
7	7P2L1B	146	184	138	0.109	0.048	0.006
1	4P5L1B	151	181	147	0.172	0.063	0.007

Table 4

Particle size composition of soil

Experimental plot No.	Horizon	Particle diameter, mm							
		>1.0	Sand		Silt			Clay < 0.001	Physical clay < 0.01
			Medium 1.0—0.25	Fine 0.25—0.05	Coarse 0.05—0.01	Medium 0.01—0.005	Fine 0.005—0.001		
6	A_1	30,6	8,9	9,6	9,0	12,3	19,1	10,5	41,9
	A_2B_1	55,8	6,6	7,3	10,6	6,8	8,7	4,2	19,7
	B_2	46,9	6,5	11,3	10,4	8,1	12,1	4,7	24,9
	C	45,5	16,0	10,6	2,3	8,6	12,1	4,9	25,6
7	A_1	27,9	6,5	14,6	6,9	10,7	18,9	14,5	44,1
	A_2B_1	56,2	4,7	4,5	9,4	6,6	10,4	8,2	25,2
	B_2	46,5	2,2	5,5	9,7	10,5	12,8	12,8	36,1
	C	56,6	7,7	6,0	6,3	8,6	6,2	8,6	23,4
1	A_1	27,6	8,0	7,3	8,8	8,6	25,0	14,7	48,3
	A_2B_1	41,9	6,3	8,3	15,4	8,8	8,8	10,5	28,1
	B_2	43,0	5,1	5,3	7,9	12,2	14,2	12,3	38,7
	C	51,7	9,5	5,2	5,0	10,3	10,2	8,1	28,5

Note: Comma represents decimal point

In addition to the mass of litter, we also determined its moisture capacity and water permeability in the natural undisturbed state in each subhorizon separately. This characterizes in some measure the water-regulating role of the litter and its variation with the composition of a plantation (Table 3).

Moisture capacity was determined by taking into account the capillary suspensed water only. Examination of the data obtained shows that the A_0'' subhorizon has the highest moisture capacity. The A_0''' subhorizon has the least moisture capacity. Moreover, as the number of larches in the composition of plantations increases, the

moisture capacity of the litter in all subhorizons increases, as a rule; this in its turn enhances its water-regulating role.

The water-permeability of the litter, as expressed by the coefficient of infiltration, is considerable, but changes noticeably within the subhorizons, increasing from the bottom to the surface. No relationship was found between water-permeability and the composition of the plantations.

Particle size composition of the soils was determined by the Kachinskiy method with a pretreatment of the soil with 0.05 N HCl (Table 4).

The considerable predominance of coarse sand and stones in soil in all horizons, except the accumulation horizon where these fractions are relatively low because of the accumulating effect of plants, is striking. Comparison of the distribution of separates in relation to the composition of plantations indicates that the maximum of fine separates (physical clay and fine silt) corresponds to the maximum number of larches in the stand composition. The decrease in the content of fine silt and clay in the eluvial horizon in all the profiles testifies to the removal of fine separates from this horizon and to the manifestation of a latent podzolization process, which is not clearly manifest in the analysis of the morphological structure of the profile.

Let us note that in plantations with the maximum number of larches removal is less pronounced than in plantations with a minimum number of these trees.

Thus, the presence of larch in the composition of plantations weakens to some extent the process of podzolization, the removal of fine soil particles. According to their particle size composition, the soils of all the profiles belong to silty, medium stony gravelly fine clay loams.

We know that the leaf-fall and phytoclimate of larch improve the soil [11]. Tkachenko [12] notes that larch promotes the transformation of nitrogen in organic matter into nitrates and assists in the transformation of potassium and phosphorus into readily-soluble compounds. According to the data of Pogrebnyak [6], larch promotes the increase in the amount of available nitrogen, phosphorus and potassium in soils. The investigations of Rozanova [8] showed that larch plantations attenuate podzol soil formation, and increase the thickness of the A + B horizon and the content of humus and exchangeable bases in the soil on account of calcium, magnesium and available forms of P_2O_5 and K_2O. The soil-improving role of larch consists, according to the data of Samusenko [10], in the increase of the content of nitrogen and phosphorus, in the considerable increase of adsorbed bases (primarily calcium), the noticeable reduction of exchangeable and hydrolytic acidity, the increase in humus content, and the improvement of the physical properties of soil. Gradoboyev [2] found that the soils of natural larch forests in Siberia have a high humus content (7-19%) and a high adsorption capacity. The degree of base saturation exceeds 90%, and hydrolytic acidity is low. As a rule, there are no clearly defined podzolization horizons. The soils are rich in total forms of nitrogen and phosphorus. The studies of Vaychis [1] have demonstrated that the soil-improving role of larch is manifest in the acceleration of the cycling of ash elements between plants and soil, although the larch litter-fall is relatively poor in them. The high rate of litter decomposition provides for the liberation of a large amount of ash elements (Ca, Mg), which become fixed in the adsorption complex. This is the reason for the sharp increase in its saturation and the decrease in acidity. Pokhiton [7] notes that larch produces a considerable increase in the content of humus in the soil and in the total adsorbed bases and also reduces actual and hydrolytic acidity as compared to pine.

The results of our chemical analyses (Table 5) show some specific characteristics of the soils studied by us.

Thus, the pH (water) varies within a narrow range, 5.7-6.2, in all the profiles. As the number of larches increases in the composition of plantations, the pH increases somewhat from weakly acid to alkaline, which is favorable to plants and microorganisms. The acidity of litter is slightly low in all the profiles.

The pH of the salt extract are lower and increase as the number of larches in the composition of the plantations increases. There is a general tendency toward an increase in the pH of both the water and the salt extract with depth. This testifies to the basic nature of the underlying rocks.

Hydrolytic acidity decreases with depth along the profile. An increase in the number of larches in the plantations also affects a decrease in hydrolytic acidity.

Let us note that as the number of larches in the plantations increases, exchangeable acidity and the content of available aluminum decrease.

The total adsorbed bases and the adsorption capacity of soils increase as the number of larches in a plantation increases. The degree of base saturation in the profiles studied differs greatly: in plantations with a maximum number of larches it reaches 74.0%, whereas in those with a minimum number of larches it is only 32.5%. This testifies to the different degree of podzolization of the soils.

Available phosphoric acid in the soils was determined by the Kirsanov method. Analysis of the data shows that the content of P_2O_5 increases with the increase in the number of larches in the plantations from 0.62 to 3.75 mg/100 g of soil.

The potassium content (according to Peyve) in the soils studied varies from 10.7-16.0 mg/100 g of soil. As the number of larches increases so does the potassium content.

The humus content in the soils was determined by Tyurin's method. Data show that the amount of humus in the accumulation horizons of the profiles is low and varies from 2.01-

Table 5

Chemical composition of soils

Experimental plot No.	Horizon	pH		Hydrolytic acidity, meq	Exchangeable acidity, meq		Total adsorbed bases, meq	Degree of base saturation, %	P_2O_5	K_2O	Humus	Dry residue	Mineral residue
		Water	Salt		A	H+A			mg/100 g		%		
6	A_0	5,6	—	—	—	—	—	—	—	—	—	0,233	0,067
	A_1	5,7	5,0	7,70	0,17	2,90	3,7	32,5	0,62	10,7	2,01	0,132	0,067
	A_2B_1	5,8	4,9	—	—	—	—	—	—	—	—	—	—
	B_2	5,8	4,9	—	—	—	—	—	—	—	—	—	—
	C	6,0	5,0	—	—	—	—	—	—	—	—	—	—
7	A_0	5,8	—	—	—	—	—	—	—	—	—	0,285	0,111
	A_1	5,9	5,2	5,60	0,07	1,45	8,3	59,7	1,16	13,3	4,39	0,082	0,016
	A_2B_1	5,8	5,1	3,63	0,15	1,30	5,3	59,6	1,25	8,9	1,63	0,067	0,022
	B_2	5,9	5,0	3,11	0,12	1,10	3,9	55,7	1,25	13,3	1,08	0,094	0,051
	C	6,0	5,2	2,49	0,17	1,05	21,2	89,5	—	8,0	—	—	—
1	A_0	5,9	—	—	—	—	—	—	—	—	—	0,305	0,125
	A_1	6,0	5,3	4,33	0,07	1,25	12,4	74,0	1,25	16,0	5,06	0,164	0,050
	A_2B_1	6,0	5,3	—	—	—	—	—	—	—	—	—	—
	B_2	6,1	5,2	—	—	—	—	—	—	—	—	—	—
	C	6,2	5,6	—	—	—	—	—	3,75	—	0,54	0,100	0,071

Note: Comma represents decimal point

Table 6

Chemical analysis of needles

Experimental Plot No.	Tree	Ash, % of absolute dry weight	In % of the weight of ash			
			SiO_2	Fe_2O_3	CaO	MgO
6	Pine	2,28	9,4	20,6	4,5	7,6
	Larch	5,50	17,8	11,4	3,4	7,0
7	Pine	2,37	9,6	17,4	5,2	10,3
	Larch	5,57	21,4	7,8	3,4	7,2
1	Pine	2,60	11,8	13,4	8,2	11,7
	Larch	5,61	26,9	7,5	4,4	9,4

Note: Comma represents decimal point

5.06%. A higher percentage of humus was found in the soil under plantations with a large number of larches.

Determinations were also made of the total water-soluble substances in the profiles, including the A_0^1" subhorizon. The dry residue (total water-soluble substances) and the ignited residue (total water-soluble mineral substances) were determined. It was found that, as a rule, soil under plantations containing larch has the highest amount of both dry residue and mineral substances. This also refers to the litter, where these indices are considerably higher than in the other soil horizons. Calcium is present only in traces.

The results obtained verify once more the conclusions of a number of investigators on the soil-improving effect of larch and on its favorable role in soil formation and in the weakening the development of podzolization.

To determine the role of needles as one of the major potential sources of enrichment of the accumulation horizons with nutrients, we studied the ash composition of pine and larch needles.

According to many investigators, the ash composition of larch and pine needles is quite different. Gradoboyev [2] notes that larch needles have a high content of ash, a large amount of silica and a low content of sesquioxides and calcium as compared to a number of other trees, including pine. A high content of ash in larch needles is reported by Kartashov [5], who notes the especially high amounts of silica and phosphorus in them. The investigations of Rozanova [9] show that the ash composition of larch needles is considerably richer than that of pine needles. Thus, nitrogen, silica, potassium and, especially, magnesium predominate in larch needles. They contain a little less potassium and phosphorus.

The results of chemical analyses of larch and pine needles are presented in Table 6.

Comparison of the data obtained shows that the total ash content of larch needles is 2-2.5 times higher than in pine. Larch needles are characterized by a higher content of silica and a lower content of iron oxides. The amount of calcium and magnesium is low, somewhat lower (especially that of calcium) than in pine. This does not agree with the results obtained by Rozanova [9]. It should be noted that although the percentage of calcium and magnesium in the ash of larch needles is relatively low as compared to pine needles, one metric ton of larch needles supplies the soil with 1.5-2.5 kg of calcium and 4.0-6.0 kg of magnesium as compared to only 1.2-2.0 and 1.7-2.2 kg, respectively, supplied by pine needles, owing to the high total ash content of larch needles. Where the pine returns this amount to the soil after several years, larch does it much faster, because of the rapid decomposition of its litterfall. This provides for a more active cycle of substances in the plantations. The large amount of silica in the needles is attributable [2] to the more active participation of larch in the chemical weathering of the parent materials.

Comparison of the results obtained for the experimental plots, taking into account the difference in the number of larches in the plantations, shows that the total ash content of both larch and pine needles increases somewhat with the increasing number of larches; there is a higher content of silica. The amount of sesquioxides in the larch and pine needles decreases as the number of larches in the plantations increases; the content of calcium and magnesium increases.

Thus the ash composition of pine as well as larch needles reproduces in some measure the chemical composition of soils. This relates to the content of both sesquioxides and exchangeable bases. At the same time the ash composition of larch needles predominates considerably over that of pine needles.

Conclusions

1. The soils of the three profiles investigated are similar with respect to morphology and physical-chemical properties and belong to the group of sod-podzolic fine clay loams. Differences in intensity of removal of fine separates, in acidity indices, in the total adsorbed bases, and in the degree of base saturation testify to the different intensity of podzol formation in the soils studied.

2. The composition of plantations influences in some measure the physical-chemical and morphological properties of soils and, what is most important, the nature of soil formation.

3. The recorded decrease in soil acidity under the influence of larch provides favorable conditions for the aerobic decomposition of organic residues; this accelerates the decomposition of litter and, consequently, the cycle of nitrients between the soil and plants.

4. The presence of larch in mixed plantations leads to the attenuation of podzol formation, as expressed in the sharp increase in base saturation (owing to the rapid decomposition of larch litter-fall), in the fixation of the soil complex and in the weakening of the removal of fine separates.

5. The increase in the thickness of the accumulation horizon, the increase in humus content, the replenishment of potassium, phosphorus and other substances and elements, which occur under the influence of larch, lead to an increase in the potential fertility of soils occupied by plantations containing larch.

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BIBLIOGRAPHY

1. VAYCHIS, M. V. 1958. Problem concerning the influence of European larch on the change of sod-podzolic soils. Pochvovedeniye, No. 6.

2. GRADOBOYEV, N. D. 1955. Soils of the larch forests of Siberia. Tr. po lesn. kh-vu, Novosibirsk, No. 2.

3. ZONN, S. V. 1954. Influence of the forest on the soil. Moscow.

4. ZONN, S. V. and D. F. SOKOLOV. 1960. Transformation of the organic matter of coniferous and broadleaf trees and their influence on the composition of humus in leached chernozem. Tr. Labor. lesoved., Vol. 1.

5. KARTASHOV, Yu. D. 1961. Characteristics of the effect on the soil of the litter-fall and litter of pine and Dahurian larch in the Olëkma River basin, Yakut ASSR. Dokl. Mosk. s.-kh. akad. im. K. A. Timiryazeva, No. 72.

6. POGREBNYAK, P. S. 1938. Exotics in mixed plantations. V zashchitu lesa, No. 6.

7. POKHITON, P. P. 1957. Influence of trees and shrubs on the physical-chemical properties of chernozem soil. Pochvovedeniye, No. 3.

8. ROZANOVA, L. M. 1955. Modification of leached chernozems under the influence of coniferous-broadleaf plantations. Author's summary of her dissertation. Moscow.

9. ROZANOVA, L. M. 1960. Cycle of ash substances and the modification of the physical-chemical properties of leached chernozems under coniferous and broadleaf plantations. Tr. Labor. lesoved., Vol. 1.

10. SAMUSENKO, V. F. 1958. Modification of the physical-chemical properties of podzolic soils under the influence of spruce and larch plantations. Sb. rabot po lesn. kh-vu VNIILM, No. 37. Goslesbumizdat.

11. TIMOFEYEV, V. P. 1961. Role of larch in increasing the productivity of forests. Izd. AN SSSR.

12. TKACHENKO, M. Ye. 1955. General silviculture. Goslesbumizdat.